Bioactive Cements for Spinal Augmentation.

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Introduction: Polymethylmethacrylate (PMMA) and Bisphenol-a-glycidyl dimethacrylate (BIS-GMA) composite cements are employed in vertebroplasty (VB) surgery. Unfortunately, these materials have drawbacks including high curing exotherms, inherent toxicity, and critically, they exhibit a modulus mismatch between cement and bone [1]. Aluminium-free, zinc-based glass polyalkenoate cements (Zn-GPCs) have none of these problems and may be suitable alternative materials for spinal augmentation. Here, one such experimental Zn-GPC, Heracap, is considered with reference to commercial VB cements, Spineplex ® (Stryker, Limerick, Ireland) and Cortoss® (Orthovita, Malvern USA), a PMMA and BIS-GMA, respectively.

Materials & Methods: One glass, $0.04SrO/0.12CaO/0.36ZnO/0.48SiO_2$ (mol. fraction), was synthesized by mixing appropriate amounts of analytical grade reagents for one hour, drying (100°C, 1Hr), then firing in a platinum crucible (1480°C, 1Hr). and quenching in water. The resultant frit was dried, ground and sieved (<45μm) before being annealed (645°C, 3Hr).

Heracap was prepared by mixing this glass with an aqueous solution of PAA (Mw = 80,800, Advanced Healthcare, UK) at a powder liquid ratio of 2:1.5. Commercial materials were used for comparison:

1. Spineplex®: powder lot #V03062006-09, liquid lot #893GN060764.
2. Cortoss® (Orthovita) lot #A603014.

Simulated body fluid (SBF) was produced in accordance with the literature [2] and utilised to determine the likely response of the three materials to bond to bone *in vivo* after seven days immersion. Any resultant surface layer deposited on the Zn-GPC was evaluated by Transmission Electron Microscopy (TEM, JEM-2011, JEOL, Japan) and Energy Dispersive X-Ray Analysis (EDS) to determine its composition.

Results & Discussion:
For Spineplex®, the SEM images (Figure 1) do not provide any evidence for the formation of an apatite layer in SBF after 7 days. There was formation of an apatite-like surface layer on Cortoss; a feature attributed to the release of ions from the silane treated glass ceramic particles. There is considerable coverage on the surface of Heracap, and the nature of this layer was evaluated by TEM and EDS.

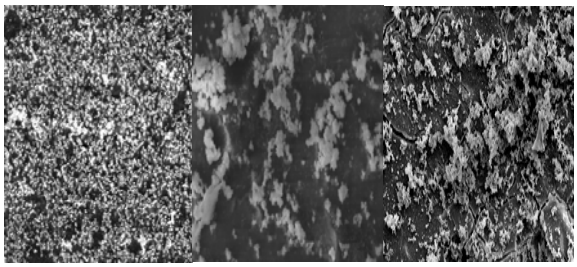

Figure 1: SEM images (X1000) of Spineplex, Cortoss & Heracap, respectively, after 7 days SBF immersion.

The surface layer on Heracap contained calcium, phosphorus, zinc and strontium and was amorphous in nature. The presence of zinc in the structure explicates the lack of crystallinity. Zinc is believed to inhibit bacterial colonisation around the cement but is also known to be effective at inhibiting HA crystallisation [4]. As such, the release of Zn^{2+} and its subsequent inclusion in the apatite layer, favours the formation of amorphous apatites.

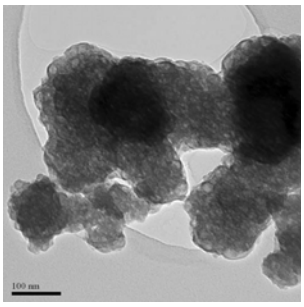

Figure 2: TEM micrograph of apatite layer on Heracap.

Conclusion
The objective of this work was to determine the likely *in vivo* response of using Heracap for spinal surgery. The handling and mechanical properties of Heracap are not reported, but the *in vivo* properties suggest that Heracap would bond to bone upon use.

References

[1] G. LEWIS. J. Biomed. Mater. Res. B. 76B (1997) 456
[2] T. KOKUBO, H. KUSHITANI, S. SAKKA, T. KITSUGI, and T. YAMAMURO, J. Biomed. Mat. Res. 24 (1990) 721
[3] D. BOYD, H. LI, D.A. TANNER, M.R. TOWLER & J.G. WALL**;** *J. Mat. Sci: Materials in Medicine* 17/6 (2006). 489
[4] A. BIGI, E. FORESTI, M. GANDOLFI, M. GAZZANO, N. ROVERI. J. Inorg. Biochem. 58 (1995) 49